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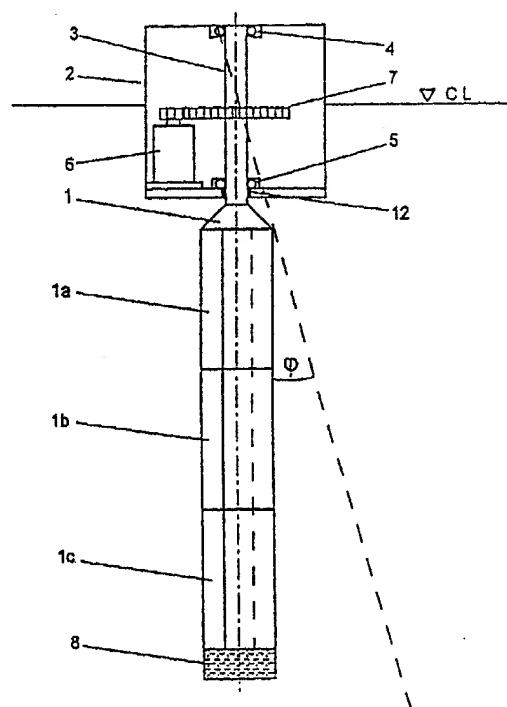
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(54) Title: METHOD AND ARRANGEMENT FOR CONVERTING KINETIC ENERGY OF OCEAN CURRENTS INTO ROTATORY ENERGY

(57) Abstract

A method and arrangement for converting kinetic energy of ocean currents into rotatory energy, using at least one turbine (1) of so-called Savonius type which is arranged to extend substantially vertically from a buoy (2) anchored in such a way in an ocean current that it cannot rotate with the turbine and driving an electric generator (6) or another rotary machine. At the bottom of the turbine (1) a counterweight (8) is provided to retain the turbine (1) substantially vertically at normal speed of the ocean current but to permit it to assume an inclined position when subjected to temporarily increased current speeds, thereby protecting the turbine from harmful flexural stresses and protecting the rotary machine (6) from being overloaded.



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Method and arrangement for converting kinetic energy of ocean currents into rotatory energy

The present invention relates to a method of converting the kinetic energy of ocean
5 currents into rotatory energy with the help of a so-called Savonius type turbine, and to use this energy for driving a rotary machine, such as primarily an electric generator.

The Savonius turbine has earlier only been used in small wind turbines having electric
generators of up to 1kW, the reason being that at high wind speeds it is subjected to high
10 flexural stresses, for which a large turbine cannot be dimensioned if it is to be capable of producing electric energy at a competitive price per kWh at average wind speeds.

In Sweden, the average wind speed is approx. 6 m/s, but during extreme conditions it can
amount to more than 45 m/s.

15 The Savonius turbine cannot be protected against high wind speeds by means of feathering, as is the case in air screw turbines, and it has only approx. 50% of the efficiency of such a turbine. It is advantageous, however, in that it is cheap to manufacture, rotates in the same direction regardless of the direction of the wind and will start already at less
20 than 1 m/s, as compared to 3-4 m/s for an air screw turbine.

If the Savonius turbine is provided with an electric generator, an electric power is produced amounting to

$$P_{el} = 0,12 \times S \times B \times H \times v^3,$$

25 S being the density of air = 1,3 kg/cu.m., H the height of the turbine in m, B its width in m and v the wind speed in m/s.

The flexural stress is proportional to the square of the wind speed and will be, for the above-mentioned speeds, $45^2 : 6^2 = 56,25$ times larger at 45 m/s than at 6 m/s.

In ocean currents, the conditions are totally different and more advantageous, as the variations in speed are much smaller. Even for tidal flows, the speed variations are very far from being as large as in the case of wind speeds. Therefore, a Savonius type turbine can, to an advantage, be used as a hydraulic turbine in ocean currents to convert their
5 kinetic energy into rotatory energy.

It is thus possible, in ocean currents, to produce environmentally compatible energy at a very competitive price in comparison with other types of energy. The density of water being $S = 1000 \text{ kg/cu.m.}$, $P_{el} = 0,12 \times 1000 \times B \times H \times v^3 \text{ Watt}$.

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The way of using a Savonius turbine in accordance with the present invention also makes it possible to obtain a kind of feathering effect on the turbine, so that neither the turbine, nor its electric generator runs a risk of being overloaded.

15 This advantageous way of using a Savonius turbine in ocean currents and of protecting the turbine and the electric generator from being overloaded has been achieved with the method in accordance with the present invention as it is defined in Claim 1.

The present invention also relates to an arrangement for carrying out the inventive
20 method. The main features of the arrangement are defined in the independent claim 7.

The invention is described in the following with reference to Figs. 1-7.

Fig. 1 is a schematic side view, partly in section, of a power plant in accordance with the
25 invention.

Fig. 2 is a schematic end view showing the turbine of the plant.

Fig. 3 shows, schematically, from above, an arrangement of 10 power plant units with
30 electric cables leading to a central unit.

Fig. 4 shows, schematically, from above, a power plant unit and its anchoring arrangement.

- 5 Figs. 5-7 show, schematically, from above, different arrangements of a number of turbines suspended from a common buoy or pontoon.

A Savonius type turbine 1 (Fig. 1) is journalled watertight with the help of seal rings or the like 12 in a floating buoy 2 with the help of a shaft 3, a ball bearing 5 and a conical bearing 4.

The turbine 1 is preferably made with three rotor units 1a -1c, one below the other and displaced 120° in relation to each other in order not to cause a turning moment which varies too much, corresponding to the relationship in a 3-phase electric motor relative to a single-phase motor.

The rotor units 1a -1c with partition walls are preferably made of high-grade sheet steel painted with a thick coat of a multi-component paint which also protects against on-growth of marine organisms.

20

In the buoy 2, an electric generator 6, such as a three-phase alternating current generator, is provided which is preferably driven via some type of step-up transmission, for example a gear mechanism 7. The turbine 1 is fitted with a counterweight 8 at its bottom, which together with the turbine's own weight is so dimensioned that when the speed of the ocean current temporarily exceeds the normal speed, the turbine will not be suspended substantially vertically from the buoy but will take up a more oblique position, the angle of which increases in relation to the increase of the speed of the current. A reduced area of the turbine blades is hereby exposed to the water current, and the water will act on the turbine at an oblique, less efficient angle than the normal one. This reduces the flexural

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stresses as well as the loading of the generator and will have an effect corresponding to that of feathering.

If the turbine is swung out to φ degrees, for example, the effect of the generator will be proportional to $\cos^3 \varphi$ and the flexural stress proportional to $\cos^2 \varphi$. In this way, a reliable, simple, robust and fully automatic overload protection is obtained.

The counterweight 8 can be made, for example, as a sand-filled box or a lump of concrete.

10

The rotatory energy produced by the turbine can also be used for other applications, for example to drive a pump in order to pump water over sorbents which extract valuable ions from the sea water.

15 In the following example, the produced electric effect P_{el} is calculated for a Savonius turbine with the height $H = 12$ m and the width $B = 4$ m in a 5-knot ocean current.

5 knots correspond to 5 nautical miles/h = $5 \times 1852 : 3600 = 2,572$ m/s.

$P_{el} = 0,12 \times 1000 \times 12 \times 4 \times 2,572^3 = 98000$ W = 98 kW.

20 At 7 knots, $P_{el} = 7^3 : 5^3 \times 98$ kW = 250 kW.

Current speeds equal to those stated above and even higher are found in large ocean areas on our planet. Tidal flow speeds of up to 15 knots can be found in narrow straits and at river mouths, which makes it possible to produce electric energy at an especially low price per kWh.

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Ocean currents often pass close to shores and can therefore be utilized without any requirement for long and, thereby, expensive electric cables on the bottom of the sea for taking the electric current ashore.

30

The electric current produced will usually show variations in frequency. With the help of known power electronics and a transformer, however, these can be eliminated and a suitable frequency and voltage obtained in order to avoid too great landing losses, whereupon the current can again, on shore, be transformed into a voltage suitable for new or existing supply networks.

A large power plant can be built consisting of, for example, ten separate buoy power stations designated B (see Fig. 3), each having a capacity in accordance with the example given above. In such a case, each buoy station B is connected by electric cables 9 to a common central buoy station 10 provided with suitable equipment, such as circuit breakers and disconnectors, transformer and protective relays, in a way known per se. From this central buoy, a common cable 11 running along the bottom of the sea connects with land.

The ten buoy power stations are arranged in a straight line or in some other optimized configuration, depending on the normal variations of the direction of the ocean current, so that they do not "steal" kinetic energy from each other. The individual buoys are anchored, preferably with the help of three anchor chains 13 with anchors 14 (Fig. 4) displaced 120° in relation to each other, so that the buoys cannot rotate with the turbine. The central buoy station 10 is also anchored in a similar way, not shown.

If the ocean current varies little in direction, or with 180° displacement - which is often the case with tidal flows - it can be suitable to place the turbines in a common buoy or pontoon 15, as shown from Figs. 5 -7 which show examples of possible configurations.

25

The buoys or pontoons should be fitted with a top-light and proper lighting in accordance with prevailing regulations.

Claims

1. A method of converting kinetic energy of ocean currents into rotatory energy,
characterized in that at least one turbine (1) of so-called Savonius type is arranged to
5 extend downwards and substantially vertically from a buoy (2) anchored in such a way
in an ocean current that it cannot rotate with said turbine (1), a shaft (3) of said turbine
being rotatably journalled in said buoy (2) and arranged to drive, preferably with the
help of a transmission device (7), a rotary machine, such as an electric generator (6),
and that, at the bottom end of said turbine (1), a counterweight (8) is fitted which,
10 together with said turbine's (1) own weight, is dimensioned to retain said turbine (1) in
said substantially vertical position at normal speed of the ocean current but to permit
said turbine (1) to assume a suitable angle of inclination (φ) when subjected to
temporarily increased current speeds, thereby protecting said turbine (1) from harmful
flexural stresses and protecting said rotary machine (6) from being overloaded.
- 15 2. A method in accordance with Claim 1, **characterized** in that said turbine (1) is fitted
with a plurality of rotor units (1a -1c) arranged one below the other on said shaft (3)
and displaced evenly in relation to each other around the circumference of said shaft
(3), preferably three rotor units displaced 120° in relation to each other.
- 20 3. A method in accordance with any of Claims 1-2, **characterized** in that, with the help
of power electronics, the electric current produced when said turbine (1) is used to
drive an electric generator (6), is converted into a suitable frequency and voltage.
- 25 4. A method in accordance with any of Claims 1-3, **characterized** in that a plurality of
power producing units (B) comprising said buoys (2) with turbines (1) are anchored to
form a group and to feed, by cables (9), the electric current produced to a collecting
buoy (10) and from there, preferably with the help of one single cable (11), to the
shore.

5. A method in accordance with Claim 4, **characterized** in that said power producing units (B) comprising said buoys (2) with turbines (1) are anchored in such a way that none of them obstructs the flow of the ocean current's kinetic energy to another unit.
- 5 6. A method in accordance with any of Claims 1-3, **characterized** in that, in the case that the ocean current varies little in direction, or always varies mainly by 180°, a desired number of said turbines (1) with electric generators (6) and other equipment required are arranged, in a suitable configuration, in a common, large buoy or pontoon (15).
- 10 7. An arrangement for converting kinetic energy of ocean currents into rotatory energy, **characterized** in that at least one turbine (1) of so-called Savonius type is arranged to extend downwards and substantially vertically from a buoy (2) adapted to be non-rotatably anchored in an ocean current, a shaft (3) of said turbine being rotatably journalled in said buoy (2) and arranged to drive, preferably with the help of a trans-
15 mission device (7), a rotary machine, such as an electric generator (6), and that, at the bottom end of said turbine (1), a counterweight (8) is provided which, together with said turbine's (1) own weight, is dimensioned to retain said turbine (1) in said substantially vertical position at normal speed of the ocean current but to permit said turbine (1) to assume a suitable angle of inclination (ϕ) when subjected to temporarily
20 increased current speeds, thereby protecting said turbine (1) from harmful flexural stresses and protecting said rotary machine (6) from being overloaded.
8. An arrangement in accordance with Claim 7, **characterized** in that said turbine (1) is fitted with a plurality of rotor units (1a -1c) arranged one below the other on said shaft
25 (3) and displaced evenly in relation to each other around the circumference of said shaft (3), preferably three rotor units displaced 120° in relation to each other.
9. An arrangement in accordance with Claim 7 or 8, **characterized** in that a plurality of power producing units (B) formed by said buoys (2) and turbines (1) are anchored to
30 form a group, and that cables (9) are adapted to feed electric current produced by said

units (B) to a collecting buoy (10) and from there, preferably with the help of one single cable (11), to the shore.

- 5 10. An arrangement in accordance with anyone of Claims 7-9, **characterized** in that a plurality of said turbines (1) with electric generators (6) are arranged, in a suitable configuration, in a common, large buoy or pontoon (15).

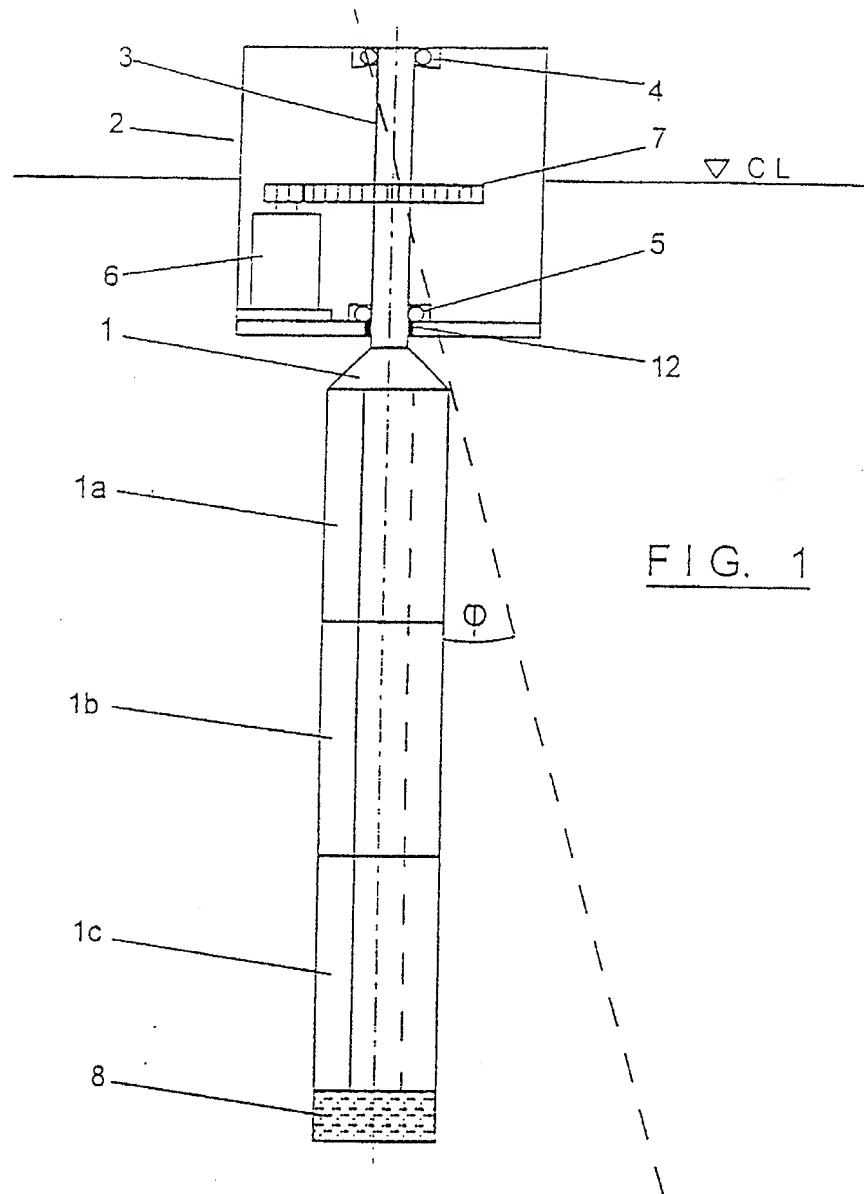


FIG. 1

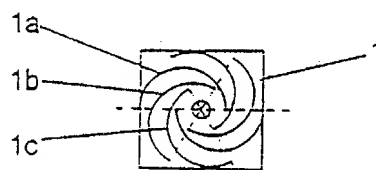
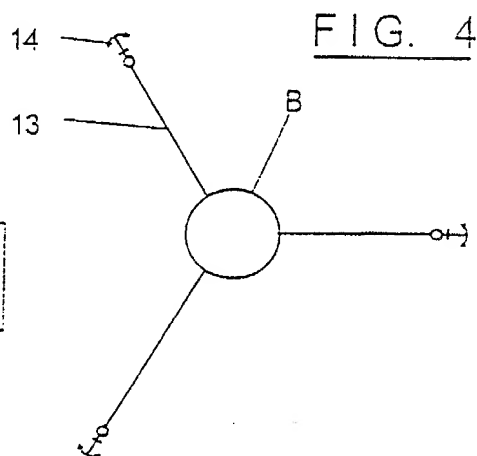
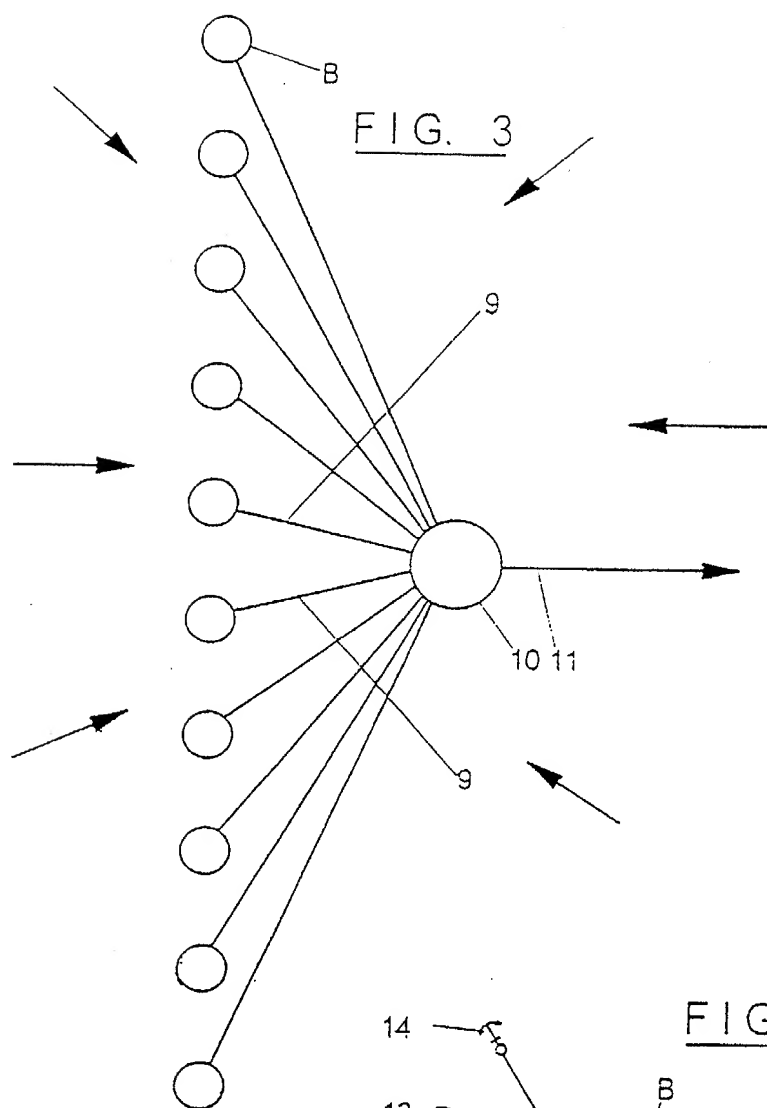


FIG. 2



← = Direction of current

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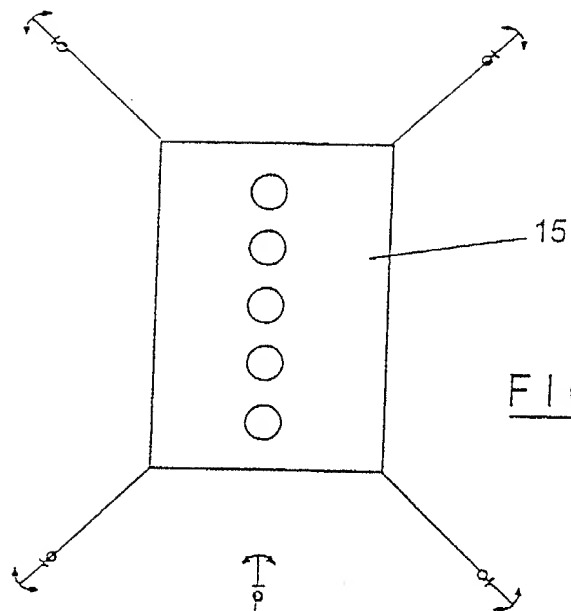


FIG. 5

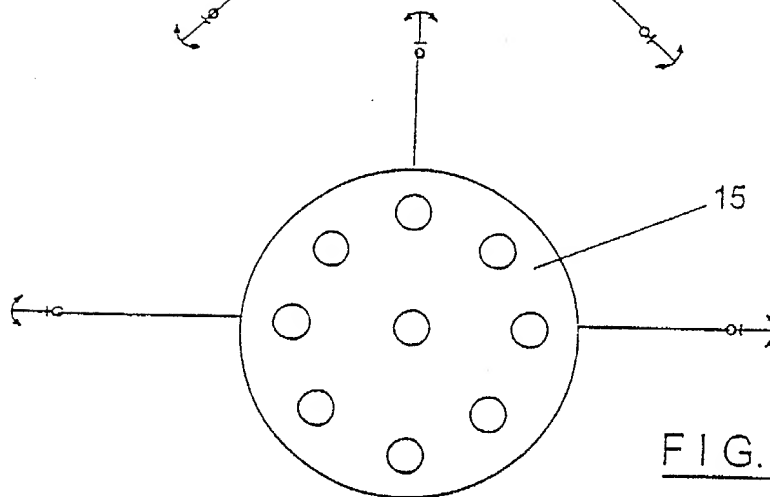


FIG. 6

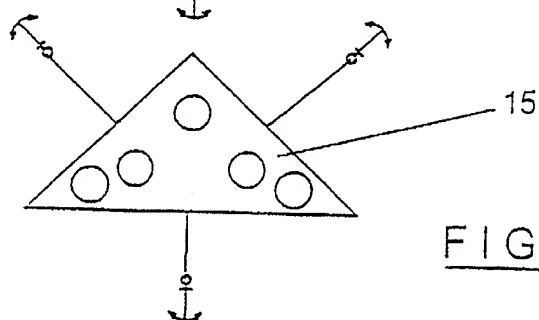


FIG. 7

INTERNATIONAL SEARCH REPORT

International application No.

PCT/SE 98/01640

A. CLASSIFICATION OF SUBJECT MATTER		
IPC6: F03B 13/22, F03B 7/00 According to International Patent Classification (IPC) or to both national classification and IPC		
B. FIELDS SEARCHED		
Minimum documentation searched (classification system followed by classification symbols)		
IPC6: F03B, F03D		
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C. DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 604211 A (G. LOFGREN), 17 May 1998 (17.05.98), figures 1-3 --	1-10
A	GB 2119449 A (EDWARD VICTOR BYERS), 16 November 1983 (16.11.83), figures 1-3 -- -----	1-10
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Patent document cited in search report			Publication date	Patent family member(s)	Publication date
US	604211	A	17/05/98	NONE	
GB	2119449	A	16/11/83	NONE	

